THE COMPREHENSION OF RAPID SPEECH
BY THE BLIND: PART III, by

EMERSON FOULKE

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THE COMPREHENSION OF RAPID SPEECH BY THE BLIND: PART III

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THE COMPREHENSION OF RAPID SPEECH BY THE BLIND: PART III

Project No. 2430
Grant No. OE-4-10-127

Emerson Foulke, Ph.D.

November, 1967

The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

University of Louisville
Louisville, Kentucky

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This report is presented in three parts. In Part I, activities during the reporting period are covered under the headings of: Completed Projects, Current Projects, and Other Project Related Activities. Two experiments are reported in detail in Parts II and III.

PART I

Project Activities

Completed Projects

Combining Methods for the Time Compression of Speech.-In the preceding report of progress, this experiment was listed as completed. However, since that time, the data have been subjected to further analysis, and the report of the experiment has been given a new title. (See PART II).

Listening Comprehension As A Function of Word Rate.-This experiment was initiated during the preceding reporting period. The data have now been collected and analyzed, and the experimental report appears as PART III of this report.

Preparation of the Proceedings of the Louisville Conference On Time Compressed Speech.-The volume of Conference Proceedings has been prepared. One thousand copies were printed, and approximately 350 copies have been distributed, at present. Requests for the volume continue to be received daily. The volume contains 168 pages and 19 chapters--an introductory chapter and a chapter of summary and conclusions, and 17 original papers, read at the Conference. The volume also contains a list of 113 references in the area of time compressed speech.

Current Projects

The Influence of Age, Grade, and Intelligence on the Comprehension of Time Compressed Speech

This experiment was discussed in the preceding report of progress. At that time, the apprehension was expressed that it might be necessary, because of organizational problems, to postpone collection of data until the Fall Semester, 1967. This apprehension was well founded. Data collection is now underway, and teams of experimenters will be visiting six or eight residential schools for the blind during the next few months.

Compressed Speech Viewed As A New Language

As indicated in the preceding report, some delay was encountered in getting this experiment underway, because of staffing problems. However, these problems have now been resolved. Mr. John Voor has been collecting data for the past several months. Subjects learn, by paired associates method, lists of words, each of which has been compressed to 35% of its original duration. Words have been chosen from the Thorndike-Lorge list of common words. Nouns, adjectives, verbs and adverbs are represented in each of the lists to be learned by subjects. When a list has been mastered to a criterion of two successive errorless trials, subjects are given trials consisting of sentences formed from these words. The experiment is not yet complete, and the results have not been analyzed. However, inspection suggests some rather interesting outcomes. First, in spite of the fact that the intelligibility of individual words has been assured by practice, subjects show very poor understanding of sentences formed from these words. Secondly, this poor performance has proved to be quite resistant to practice. Even after many trials with sentences, subjects are unable to understand as many as half of them. Finally, although subjects can often recall many of the words in sentences, the order in which words are recalled is frequently incorrect. These findings suggest that when speech rate is too high, the listener may be presented with insolvable problems of cognitive processing. The operations involved in the perception of spoken language require time and, if not enough time is allowed for these operations, the perception of spoken language will deteriorate.

An Examination of the Relative Distortions of Various Speech Sounds

At the time of the last report on this project, lists of phonetically balanced words had been compressed in time by various amounts, and spectrographic records of these compressed words had been prepared by Miss Jane Gaitenby, at Haskins Laboratory. Dr. Anthony Holbrook, Director, Speech Science Laboratory, Department of Speech, The Florida State University, Tallahassee, Florida 32306, has agreed to assist in the interpretation of these records, and they are in his possession at the present time.

Separation of the Effects of Word Rate and Time Compression

As indicated in the last report, this experiment will be performed by Miss Ruth Ann Overmann, and reported in her master's thesis. At present, she is engaged in the preparation of the materials to be used in the experiment.

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The Experimental Control of Listening Difficulty

The experiment described in the last report, in which Mr. Ronald Reid, a graduate student in the Audio Visual Department at Indiana University, determined the comprehension of listening selections, the difficulty of which had been experimentally manipulated by performing certain operations on their grammar and vocabulary, has been completed. The data have been analyzed and Mr. Reid is now preparing an account of the experiment as his doctoral dissertation. A report of the experiment will also appear in a subsequent progress report. A brief summary of the findings, written by Mr. Reid, follows:

> In order to investigate the effect on comprehension of the difficulty of material that is time compressed, an experiment was designed in which certain features of language construction that characterize "difficult" material were specifically defined and used as guides in developing "simplified" material. The comprehension tests, Forms A and B of the Nelson-Denny Reading Test, were rewritten in order to edit the language construction and make it more clear and concise. Five rules of grammar and principles of composition that characterize a high level of "readability" of material were used as guides in rewriting the material. The rewriting resulted in linguistically simplified versions of the comprehension tests. The independent variables, arranged in a 2 x 2 x 2 x 4 factorial design, were, respectively, (1) at which university the data was collected, Louisville or Indiana, (2) which of two equivalent forms of the material was used, Form A or B, (3) which of two levels of difficulty of material was used, original version or simplified version, and (4) which of four rates of presentation were used, 175, 275, 325, or 375 words per minute. The dependent variable was the number of correct responses to test questions. The inter-form reliability of the test is said to be 0.81. The analysis of covariance was used to test the statistical significance of these effects. Scholastic Aptitude Test score was the adjusting variable.
>
> The results show the following three main effects to be significant at the .01 level of significance: (A) form of material; (B) difficulty of material; (C) rate of presentation. The two following interactions were significant at the .05 level of significance: (A) university x form; (B) form x difficulty.
>
> ### Main Effects
>
> Both versions of Form B of the test resulted in greater average comprehension compared with both versions of Form A. The adjusted mean for the combined versions of Form A

was 21.05, and the adjusted mean for the combined versions of Form B was 23.1.

The simplified versions of the test resulted in greater average comprehension than the original versions of the test. The adjusted mean for the original version of the test was 21.05, and the adjusted mean for the simplified versions was 23.15.

Comprehension varied significantly as a function of rate of presentation. However, the curve for the function was more or less flat until 325 and then dropped off steeply. The adjusted means for the rates of presentation were 22.65 at 175 wpm, 24.4 at 275 wpm, 22.55 at 325 wpm, and 18.75 at 375 wpm.

Interactions

The differences between the adjusted means for universities varied significantly from one form of the test to the other. The adjusted means for the Louisville group were 21.9 for Form A and 23.5 for Form B. The adjusted means for the Indiana group were 20.2 for Form A and 22.7 for Form B. Thus the Louisville subjects on the average scored 1.6 items higher on Form B than on Form A, while this difference for Indiana subjects was 2.5.

The differences between adjusted means for difficulty levels varied from one form to the other. The adjusted means were as follows: Form A, original version 19.0, simplified version 23.0; Form B, original version 23.0, simplified version 23.1. Thus, simplifying Form A resulted in higher comprehension, while simplifying Form B had no effect on comprehension.

The Influence of Neural and Anatomical Damage on the Comprehension of Accelerated Speech

In the last progress report, research was considered in which patients with hearing disorders caused by peripheral or central damage would be tested for word intelligibility and for listening comprehension, using time compressed speech. It was hoped that such research would make a valuable contribution to the analysis of the perceptual problems imposed by accelerated speech. However, it has not been possible to locate enough subjects in this community with hearing disorders of appropriate genesis to pursue this line of research further. Therefore, this project has been set aside for the time being with the hope that, at some future time, the subjects required for its prosecution may become available.

The Comparison of Conventional Speech and Dichotic Speech With Respect to the Intelligibility of Single Words

This experiment, described in the preceding progress report, has been assigned to Miss McLean, who has joined the project for the

Fall Semester, 1967. The materials for this experiment have now been assembled, and data collection will commence shortly.

The Center for Rate Controlled Recordings

The Center for Rate Controlled Recordings has now been established and the services it is prepared to offer have been advertised in a modest way. Six newsletters have been issued. For the time being, these newsletters are being prepared by Mrs. Cynthia Graae, at the American Institutes of Research, because of temporarily inadequate staff and facilitites at the Center. Mrs. Graae has done an excellent job in preparing the newsletters and, judging by the steady stream of requests for inclusion on its distribution list, the newsletter has served the intended function of stimulating and sustaining interest in the area. Three board meetings of the Center have been held, and a fourth meeting will be convened this Fall. An application for support of Center functions has been prepared, under the critical scrutiny of board members, and has been submitted to the Office of Education for evaluation.

The Average Oral Reading Rate

In order properly to appreciate the significance of a given accelerated word rate, it is necessary to have better information about average oral reading rates for various readers and kinds of material. Miss McLean, who is temporarily affiliated with the project, has recently completed the collection of a large number of samples of the oral reading of Talking Book readers. Included in her collection are samples from many different readers, and from different categories of reading material. These samples will be used in determining both word rate and syllable rate, and comparsions will be made among readers and categories of reading material. This project was made possible by the cooperation of the Wolfner Memorial Library for the Blind in St. Louis, Missouri, one of the regional libraries that distributes Talking Books provided by the Library of Congress. Miss McLean spent two days at the Wolfner Library, collecting tape recorded samples from Talking Book Records.

The Influence of Initial Word Rate on the Comprehension of Time Compressed Speech

When speech is sufficiently compressed in time, there is a loss in comprehension. The process of compression degrades, to some extent, the intelligibility of the words that constitute a listening selection. Another consequence of compression is that the words in a listening selection occur at a faster rate. Current evidence suggests

that the loss in comprehension is due primarily to the increase in word rate. However, this problem can be examined further by testing for the comprehension of a listening selection that has been read by the same reader at several different word rates, and compressed to the same final word rate. If the versions of the listening selection generated in this manner differ with respect to listening comprehension, it may be concluded that the process of compression has affected the comprehension of the selection. If no differences in comprehension are found, support is provided for the hypothesis that word rate rather than word intelligibility is primarily responsible for the loss in comprehension. An experiment of this sort is now underway. A listening selection has been read by the same reader at three different word rates, and these three renditions have been compressed to a final rate of 275 wpm and a final rate of 325 wpm. The six versions of the listening selection generated in this way are heard by subjects, who are then tested for listening comprehension. Approximately half of the subjects have been tested so far.

Other Project Related Activities

Miss Florence Elizabeth McLean, a senior student at Webster College in St. Louis, Missouri, is spending her sabbatical leave at the University of Louisville, and will be working on the compressed speech project in order to gain research experience. She will receive training in the collection and analysis of data, and in report writing.

On August 24, 1967, the principal investigator was interviewed regarding the compressed speech project by Mr. Dick McMahon, a staff announcer at Radio Station WSM, Nashville, Tennessee. This interview was broadcast on WSM on the night of September 11, 1967, and rebroadcast on MONITOR, the NBC weekend program, on Saturday, September 16, 1967. On August 11, the principal investigator presented an account of his research on time compressed speech to the "Summer Session on Special Education and Technology" presented by Columbia University in collaboration with the Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology.

On October 25, 1967, the principal investigator described speech compression methods and present findings of research on time compressed speech to a group of superintendents of residential schools for the blind who were attending the Administrator Workshop, organized by the American Association of Instructors of the Blind, held at the Brown Hotel, Louisville, Kentucky. The principal investigator made a similar presentation to the Regional Conference of the American Association of Instructors of the Blind, held at Harrisburg, Pennsylvania, on November 10 and 11, 1967.

PART II

THE COMPREHENSION OF CONNECTED DISCOURSE AS A FUNCTION OF WORD INTELLIGIBILITY

A spoken word is intelligible if, when presented in isolation, it can be reproduced accurately by a listener. Comprehension is revealed by the ability to demonstrate knowledge of the facts and implications of a listening selection. The behavior that constitutes the evidence for word intelligibility requires only the short term storage of a stimulus item necessary for immediate recall. The behavior that constitutes the evidence for comprehension requires, in addition, encoding and decoding processes, and long term storage.

There is, of course, a relationship between word intelligibility and listening comprehension. If the individual words of a listening selection were completely unintelligible, the listener could not comprehend the listening selection. However, there are reasons to believe that a point is reached beyond which further improvements in the intelligibility of the words in a listening selection will not result in further gain in listening comprehension.

Garvey (1953) compared the intelligibility of words compressed in time by reproducing a tape at a faster speed than the one used during recording with words compressed in time by a sampling procedure in which brief segments of the recorded tape were regularly eliminated. The first method results in an elevation of vocal pitch that is proportional to the increase in playback speed of the recorded tape. The second method leaves the pitch of the speaker's voice undisturbed. When, by increasing tape playback speed, words were reproduced in 50% of the time required for original production, there was a 35% loss in intelligibility, and a 92% loss in intelligibility when they were reproduced in 40% of the original production time. On the other hand, when, by the sampling method, words were reproduced in 50% of the original production time, there was only a 5% loss in intelligibility, and a 7% loss in intelligibility when they were reproduced in 40% of the original production time. The two methods of time compression have the same effect on the rate at which speech sounds occur. However, since compression by increasing tape playback speed elevates vocal pitch while compression by periodic sampling does not, it is probably the elevation in vocal pitch that is primarily responsible for the loss in intelligibility.

However, when the two methods for the time compression of speech were compared with respect to the comprehension of connected discourse, there was little or no difference between them. McLain (1962) compressed a listening selection to 54% of its original production time by each of the two methods. The comprehension test scores of

two groups of subjects who had listened to these compressed selections were compared and a statistically significant but rather small difference in favor of the sampling method was found. Foulke (1966) performed a similar experiment in which a listening selection was compressed to 70% (250 wpm), 58.33% (300 wpm), and 50% (350 wpm), of the original production time by each of the two methods. The groups of subjects who heard the six resulting versions of the listening selection were tested for listening comprehension. There was no difference in the outcome of the experiment that could be associated with the method used for time compression. Thus, the difference in favor of the sampling method, when the comparison is made in terms of word intelligibility, largely or completely disappears when the comparison is made in terms of comprehension.

It is possible, by combining the two methods for the time compression of speech, to hold constant the rate at which speech sounds occur, while varying the amount of distortion in vocal pitch. That is, if, for each of several versions of a listening selection, the two methods for time compression are combined in different proportions to produce the same final accelerated word rates, the resulting versions of the listening selection will vary with respect to distortion in vocal pitch. Since there is a strong relationship between distortion in vocal pitch and word intelligibility, this scheme provides a method for varying word intelligibility systematically. Of course, the versions resulting from this treatment will also vary with respect to the amount of speech information that has been discarded. But, as has already been shown, the sampling method has a relatively small influence on word intelligibility.

The finding that it is not necessary for all of the words in a listening selection to be intelligible in order for that selection to be comprehensible is explained by the ability of the listener to make use of the redundancy in spoken language to recover missed words or meanings (Miller and Selfridge, 1950). Klumpp and Webster (1961), for instance, report higher identification scores for time compressed phrases than for time compressed single words. However, a more systematic exploration of the relationship between word intelligibility and the comprehensibility of connected discourse would promote a better understanding of the cognitive contribution of the listener to the task of comprehending. In the experiment, the report of which follows, the word intelligibility of a listening selection has been varied systematically by varying the distortion in vocal pitch, while holding word rate constant.

Method

Subjects

One-hundred-sixty-one seventh, eight, and ninth grade pupils, of both sexes, from four residential schools for the blind,

served as subjects in the experiment. Subjects were assigned to five experimental groups in such a way that the proportional representation of schools and of grades was approximately the same for all groups. The five groups contained 34, 34, 29, 32, and 32 members respectively.

Experimental Materials and Apparatus

The listening selection was a 3,350 word fictional account of a boy's encounter with a band of pirates on a desert island. It was judged to be appropriate in interest and difficulty for children in the seventh, eighth, and ninth grades (Allen, 1958). This selection was read orally by a professional reader and recorded on magnetic tape by means of an Ampex Tape Recorder, Model 300, in the Talking Book Studios of the American Printing House for the Blind.

This "master tape" was used to prepare five versions of the listening selection, each compressed to approximately 54% of its original length. This magnitude of compression was chosen because previous research (Fairbanks, Guttman, and Miron, 1957; Foulke, Amster, Nolan, and Bixler, 1962) has shown it to be in the middle of the range in which changes in compression are accompanied by changes in listening comprehension. If word intelligibility is a factor in listening comprehension, its systematic variation should affect the comprehension of speech compressed by this amount. Version 1 was made by reproducing the "master tape" on the Tempo Regulator[1] at the desired amount of compression. The output of the Tempo Regulator was recorded on the tape to be used in the experiment by means of a Crown Tape Recorder, Model 800. Thus, the compressed speech in Version 1 was accomplished entirely by the sampling method, and it was free from distortion in vocal pitch. In Version 2, the "master tape" was reproduced on the Tempo Regulator, adjusted for three-fourths of the desired compression in time, and its output was recorded on tape by means of the Crown Tape Recorder. The remaining compression was accomplished by reproducing this tape at a faster speed than the one used during recording, and this speeded reproduction was recorded on tape to be used in the experiment. In Version 3, half of the desired compression was accomplished by each method. In Version 4, one-fourth of the desired compression was accomplished by the sampling method, and the remaining three-fourths by increasing tape playback speed. In Version 5, all of the compression was accomplished by increasing tape playback speed. Although the five versions of the listening selection prepared in this manner were approximately the same with respect to word rate, (approximately 325 wpm), there was a progressive elevation in vocal pitch from Version 1 to Version 5.

The tapes used in the experiment were reproduced on a Uher Tape Recorder, Model 4000, and its output was distributed to the

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[1] The Information Rate Changer, the successor to the Tempo Regulator, is currently available from the Gotham Audio Corporation, 2 West 46th Street, New York, New York.

Western Electric Headsets, Type ANB-H-1, worn by the subjects. The headsets were fitted with circumaural ear cushions, and equipped with volume controls, so that the signal level could be adjusted by each subject for comfortable listening.

A 42 item, four alternative multiple choice test, with a split-half reliability of .76, was prepared for the listening selection. Test questions were read orally by a skilled reader, and recorded on magnetic tape by means of a Crown Tape Recorder, Model 800, in the compressed speech laboratory at the University of Louisville. Each item, including its four alternatives, was read twice. Special answer sheets were prepared for use by blind students. For each item, the student indicated his choice of alternatives by making a pencil mark in one of four areas, outlined by braille dots and designated by braille letters.

Procedure

All of the subjects at a particular school for the blind that qualified for membership in a particular experimental group were tested at one time. First, subjects heard the tape recorded instructions for participating in the experiment, and were given practice trials in marking their answer sheets. Then, the appropriate version of the compressed listening selection was presented. Following this, the tape recorded test questions were presented and subjects marked their answer sheets. If necessary, the tape recorder was stopped between questions, until all subjects had made their choices. However, it was usually unnecessary to stop the tape recorder. This testing arrangement avoided the problem of keeping one's place, which is a serious problem for braille readers who must alternate between a question booklet and an answer sheet. It also assured that each subject attempted every item on the test.

Results

Each subject's score was the number of test items correctly answered. The means and standard deviations of these scores, for the five experimental groups, are shown in Table 1. It is clear that the different experimental treatments produced very little difference in mean test scores. An analysis of variance of test scores (See Table II) indicated no significant differences among test scores that could be associated with experimental treatments.

TABLE I

MEANS AND STANDARD DEVIATIONS OF COMPREHENSION TEST SCORES

Groups	I	II	III	IV	V	
n=	34	34	29	32	32	N=161
M=	18.6765	18.7941	19.7241	19.2187	18.9688	
SD=	9.0410	8.0896	7.6807	7.1108	7.6581	

TABLE II

ANALYSIS OF VARIANCE OF COMPREHENSION TEST SCORES

Source of Variation	df	SS	MS	F
Between Groups	4	21.2664	5.3166	.0838*
Within Groups	156	9895.2305	63.4310	
Total		9916.4969		

*Not significant at the .25 level.

Discussion

Within the range in which word intelligibility was varied in this experiment, it exerted no influence on the comprehension of connected speech. If intelligibility had been degraded sufficiently, there doubtless would have been a loss in comprehension. Nevertheless, within broad limits, listening comprehension does not appear to depend very heavily upon the intelligibility of single words. There is apparently enough redundancy in spoken language so that many words can be transmitted imperfectly, or not at all, without interfering seriously with listening comprehension. As a listener acquires experience with his language--its grammar and its conventional forms--he acquires information about the probabilities associated with the occurrence of particular words, given the occurrence of particular preceding words. Similarly, the context of meanings aroused by a listening selection reduces the listener's uncertainty, at any given instant, regarding the words and phrases that are to follow. The listener is able to use this information concerning the probabilities associated with the occurrance of words, phrases, or sentences, to reconstruct imperfectly transmitted speech.

When the outcome of this study is considered, together with the outcome of the studies in which the dependence of listening comprehension upon word rate has been investigated, it appears that listening comprehension depends more upon word rate than upon word intelligibility. If, within broad limits, listening comprehension is not markedly influenced by word intelligibility, the decline in the comprehension of speech that has been compressed in time, cannot easily be explained by the degradation of the signal imposed by the process of compression. In any case, as has already been mentioned, words can be compressed by the sampling method to less than half their original duration without a serious loss in intelligibility. The loss in comprehension at fast word rates is due not to faulty stimulus registration, but to the presentation of words at a rate that is faster than the rate at which the listener can process them.

The method employed in this experiment provides a way of investigating the contribution of the listener, with his background of experience, to the perception of spoken language. Since word intelligibility can be systematically degraded, the listener can be forced into progressively greater reliance upon his store of information regarding word probabilities in restoring imperfectly transmitted messages.

If the listener's ability to tolerate degradation of word intelligibility is explained by the redundancy in spoken language, the effect of degrading word intelligibility should depend upon the redundancy of the language to be heard. An experiment in which comprehension is determined, as a function of word intelligibility, for messages the redundancy of which has been varied by the technique reported by Miller and Selfridge (1950), should be illuminating.

PART III

LISTENING COMPREHENSION AS A FUNCTION OF WORD RATE

If word rate is determined for a large number of samples of the oral reading of professional readers, such as radio newscasters or those who read Talking Books, considerable variability will be observed. This variability is the consequence of differences in the nature of the material that is read, and to differences in personal reading style. However, the mean word rate will be approximately 175 wpm (Johnson, Darley, and Spriestersbach, 1963; Foulke, Unpublished Data). Recent technological developments (Fairbanks, Everitt and Jaeger, 1954; Foulke, 1964; Scott, 1965), have made it possible to vary word rate of recorded oral reading over a wide range, either slower or faster than normal, without distortion in vocal pitch. This capability raises the possibility of presenting speech at other rates than the one at which it happens to be produced by an oral reader. On the practical side, recorded speech at a faster than normal rate can provide a needed increase in reading speed for blind people, and other people who read by listening. Recorded speech at slower than normal rates may prove to be a useful tool in promoting certain kinds of instruction, such as the learning of a foreign language. In a more theoretical vein, the ability to vary speech rate through a wide range, suggests new avenues for investigating the cognitive processes that underlie the perception of speech.

There are several studies in which comprehension has been measured as a function of word rate; but, in each of these studies, word rate has been varied through a relatively limited range. Therefore, in order to gain an impression of the influence of this variable, it has been necessary to combine the results of several studies. Within the range extending from 126 to 172 wpm, Diehl, White and Burk (1959), found listening comprehension to be unaffected by changes in word rate. In the range extending from 125 to 225 wpm, Nelson (1948) and Harwood (1955) found a slight, but insignificant loss in comprehension as word rate was increased. Fairbanks, Guttman, and Miron (1957), found little difference in the comprehension of listening selections presented at 141, 201, and 282 wpm. Thereafter, comprehension, as indicated by percent of test questions correctly answered, declined from 58% correct at 282 wpm to 26% at 470 wpm. Foulke, Amster, Nolan and Bixler (1962), using both technical and literary listening selections, found comprehension to be only slightly affected by increasing word rate up to 275 wpm. However, in the range extending from 275 to 375 wpm, they found an accelerated decrease in comprehension as word rate was increased. Foulke and Sticht (1967), using the STEP Listening Test, Form 1A, found a decrease in comprehension

of 6% between 225 and 325 wpm, and a decrease of 14% between 325 and 425 wpm. The last three studies cited are in agreement regarding the finding that there is a change in the rate at which comprehension declines as word rate is increased. A similar relationship has also been found in many other studies in which the determination of the influence of word rate on listening comprehension was not the primary objective (Foulke, 1966).

The purpose of the study reported in this paper is to display the way in which listening comprehension varies as word rate is varied over a wide range. It is felt that a more certain knowledge of the relationship between these variables will be useful in making decisions about the rate at which to present recorded speech, in both practical and theoretical applications.

Method

Subjects

Three-hundred-sixty college students of both sexes, drawn from psychology and education classes at the University of Louisville, served as subjects. In a majority of instances, their service fulfilled a course requirement. Subjects were divided into twelve experimental groups, with 30 subjects per group.

Experimental Materials and Apparatus

A 2,925 word listening selection, appropriate in interest and difficulty for a college population, was chosen for use in the experiment (Durant, 1957). A 50 item four alternative multiple choice test, with a split half reliability of .68, was written for this selection.

The selection was read orally by a professional reader and recorded on magnetic tape by an Ampex Tape Recorder, Model 300, in the Talking Book Studios of the American Printing House for the Blind. This "master tape" was reproduced on a modified Tempo Regulator (Foulke, 1964), an electromechanical device for the compression or expansion of speech (Fairbanks, Everitt and Jaeger, 1953). The Tempo Regulator was adjusted for one of the word rates to be used in the experiment, and its output was recorded on magnetic tape by a Crown Tape Recorder, Model 800. Instructions for participating in the experiment were also recorded on this tape. Twelve tape recorded versions of the listening selection were prepared in this manner, covering the range from 125 through 400 wpm in steps of 25 wpm. The tapes used in the experiment were reproduced on a Wollensak Tape Recorder, Model T1500. The output of the tape recorder was distributed to the Western Electric Headsets, Type ANB-H-1, fitted with ear cushions,

and each headset was provided with a volume control so that the signal level could be adjusted by the subject for comfortable listening.

Procedure

It was not possible to obtain the assistance of enough subjects at any one time so that a complete experimental group could be tested at one setting. Therefore, subjects were tested in groups that ranged from 10 to 20 in number, and tests were conducted at a given word rate until the 30 subjects required for that condition of the experiment had been tested. Starting with the slowest word rate used in the experiment, the listening selection was presented to succeeding experimental groups in ascending order of word rate.

The experiment was conducted in a large university classroom, with the poor acoustical properties typical of such rooms. However, since all subjects listened by means of headsets fitted with the kind of circumaural ear cushions that completely surrounds and encloses the external ear, the listening environment was felt to be satisfactory and similar for all subjects.

First, test booklets and answer sheets were distributed. Next, subjects heard the recorded instructions for participating in the experiment. Then, the listening selection was presented. Upon its conclusion, subjects proceeded immediately to the test of listening comprehension, and upon its completion, each subject turned in his test materials and quietly left the room. Each experimental session was concluded within the 50 minute class period.

Results

A corrected test score was determined for each subject by applying to his raw score the formula $CS = R - [W \div (n-1)]$ where CS = corrected score, R = right answers, W = wrong answers, and n = the number of alternatives in the test item (Cronbach, p. 50). A correction for guessing was applied to raw test scores because it was felt that the assumptions underlying a correction of this sort are reasonably met when experimental group means are to be compared. The means and standard deviations of corrected test scores, for each of the 12 experimental groups, are shown in Table 1. The relationship between word rate and mean test score is displayed graphically in Figure 1. Word rate is scaled on the abscissa, and test score on the ordinate. Though the curve in Figure 1 is somewhat irregular, the relationship suggested by it is one in which comprehension is relatively unaffected by changes in word rate in the range bounded by 125 and 250 wpm. Beyond this range, however, comprehension declines rapidly as word rate is increased.

TABLE I

MEANS AND STANDARD DEVIATIONS OF COMPREHENSION TEST SCORES AS A FUNCTION OF WORD RATE

WPM	M	SD
125	49.33	12.86
150	48.71	12.97
175	44.79	14.73
200	42.39	12.79
225	47.28	15.97
250	45.05	15.52
275	37.96	14.17
300	39.11	12.74
325	30.58	17.90
350	29.87	16.18
375	23.73	14.16
400	20.27	11.20

TABLE II

ANALYSIS OF VARIANCE OF COMPREHENSION TEST SCORES

Source of Variation	df	SS	MS	F
Between	11	32,524.1534	2,956.7412	14.79*
Linear	(1)	.9232	.9232	
Within	348	69,559.5307	199.8837	
Total	359	102,083.6841		

*p < .01

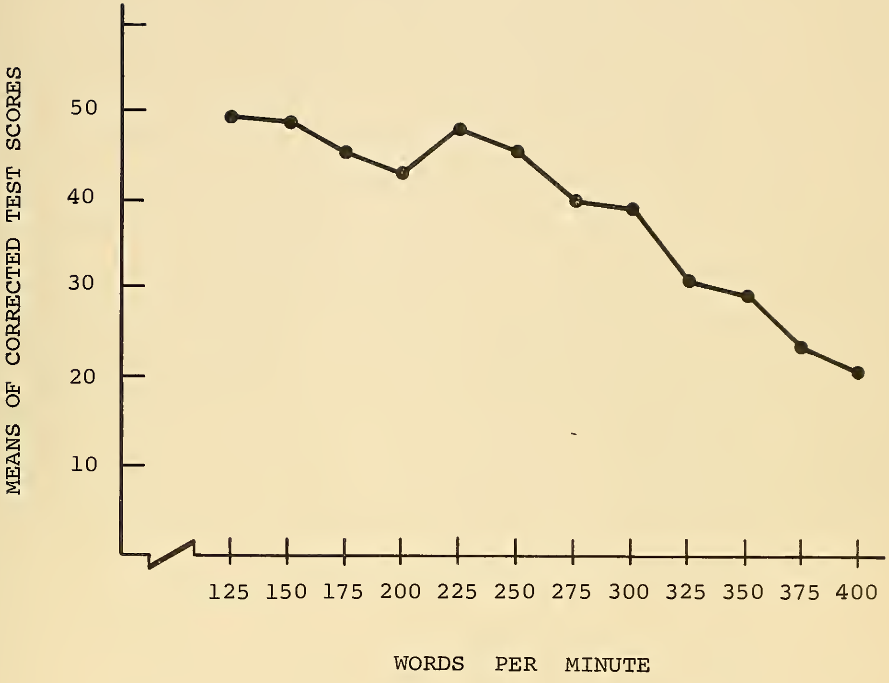

Figure 1. Comprehension as a function of word rate.

TABLE III

NEWMAN-KEULS ANALYSIS OF THE SIGNIFICANCE OF DIFFERENCES AMONG GROUP MEANS

WPM	125	150	175	200	225	250	275	300	325	350	375	400
125	125	150	175	200	225	250		300				
150	125	150	175	200	225	250	275	300				
175	125	150	175	200	225	250	275	300				
200	125	150	175	200	225	250	275	300				
225	125	150	175	200	225	250	275	300				
250	125	150	175	200	225	250	275	300				
275		150	175	200	225	250	275	300	325	350		
300	125	150	175	200	225	250	275	300	325	350		
325							275	300	325	350		
350							275	300	325	350	375	
375									325	350	375	400
400											375	400

The test scores used in plotting Figure 1 were examined by an analysis of variance, the results of which are shown in Table II. The variance in test scores associated with changes in word rate is significant beyond the .01 level as shown in row 1 of this table.

The significance of the difference between ordered pairs of individual means was examined by means of the Newman-Keuls Test for Ordered Pairs of Means. The results of this analysis are shown in Table III. This table is cast in matrix form, with the word rates at which tests were conducted arranged down the left hand margin and across the top of the matrix in order of increasing magnitude. Entered in each row, under the appropriate column headings, are the word rates for which comprehension scores were not significantly different from the comprehension score associated with the word rate in the left hand margin that identifies the row. The results presented in Table III strongly reinforce the impression conveyed by Figure 1. The pattern formed by the entries in this table clearly depicts the nature of the relationship between word rate and listening comprehension. Listening comprehension does not vary significantly as word rate is increased, in the range extending from 125 to 250 wpm. However, further increases in word rate result in losses in comprehension that are too large to be accounted for by chance fluctuation of test scores. The mean comprehension score of 20.27, obtained at 400 wpm, though quite low, was significantly different from zero, suggesting that there was some comprehension at this word rate. However, in order to be confident that this mean comprehension score had been determined primarily by the listening experience provided the subjects, it would have been necessary to administer the test of comprehension to another group that had not listened to the selection, and this was not done.

The relationship between word rate and listening comprehension, suggested by Figure 1 and Table III, is apparently not linear. The hypothesis of linearity was rejected by the test for linearity shown in row 2 of Table II.

Discussion

The results of the present experiment are in close agreement with those of other experiments in which the relationship between word rate and listening comprehension has been studied. In previous investigations (Foulke, Amster, Nolan & Bixler, 1962; Fairbanks, Guttman, & Miron, 1957) increasing word rate had little effect on listening comprehension below approximately 275 wpm. Increasing word rate beyond 275 wpm resulted in a rapid decline in comprehension. In the present study, the rapid decline in comprehension set in beyond 250 wpm.

From a practical point of view, this study, because of the large number of subjects employed, and because of the large number of word rates at which comprehension was determined, provides a firmer basis

for making recommendations regarding accelerated word rates that might safely be considered in those situations in which time compressed speech is to be used to promote faster aural communication. Of course, relevant experience might be expected to bring about some improvement in the ability to comprehend accelerated speech, and the subjects in this experiment had no such experience, prior to the experiment. Voor and Miller (1965), for instance, have demonstrated a slight improvement in comprehension during initial practice trials. However, except for this "warm up" effect, the training experiences that have been devised so far, have had little effect on the ability to comprehend accelerated speech (Foulke, 1964; Orr, Friedman, & Williams, 1965). Until successful training methods are developed, the present findings should constitute a fairly accurate picture of the relationship between word rate and listening comprehension.

The present findings also support a hypothesis suggested by Foulke and Sticht (1967) regarding the perceptual problem that an accelerated word rate creates for the listener. According to this hypothesis, the loss in comprehension that attends an increase in the word rate of speech that has been accelerated by the sampling method is due not to a degradation of word intelligibility, but to a reduction in the perception time needed by the listener to process incoming speech information. Two kinds of evidence were cited in support of this hypothesis. First, it has been shown (Garvey, 1953; Fairbanks & Kodman, 1957; and Kurtzrock, 1957), that word intelligibility remains at a high level well beyond the compression in time at which the comprehension of connected discourse has begun to fall rapidly. Secondly, experiments by Foulke & Sticht (1967), Foulke, Amster, Nolan and Bixler, (1962), Fairbanks, Guttman, & Miron, (1957), Diehl, White, & Burk, (1959), Nelson (1948), and Harwood (1955), when considered collectively, suggest that listening comprehension is little affected by increasing word rate until the neighborhood of 275 wpm is reached, but substantially affected thereafter. It appears that word rate can be increased to some extent without depriving the listener of the perception time required to process the speech input. However, once the point has been passed at which perception time is no longer adequate, listening comprehension begins to decline rapidly. The difficulty with the evidence concerning listening comprehension just cited is that word rate has not been varied over a wide enough range in any single experiment, and not enough determinations have been made within the ranges employed. The present experiment provides confirmation for the impression gained by combining the results of the several experiments just mentioned.

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